IS 15977 : 2013
(Superseding IS 7280 : 1974 and IS 3613 : 1974)

(Reaffirmed 2019)

भारतीय मानक

संरचना इस्पात की निमग्न आर्क वेल्डिंग के लिए खुली ठोस तार इलैक्ट्रोड एवं तार फ्लक्स कंबिनेशन के वर्गीकरण एवं स्वीकार्य परीक्षण — विशिष्टि

Indian Standard

CLASSIFICATION AND ACCEPTANCE TESTS FOR BARE SOLID WIRE ELECTRODES AND WIRE FLUX COMBINATION FOR SUBMERGED ARC WELDING OF STRUCTRUAL STEEL — SPECIFICATION

ICS 25.160.20

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Welding General Sectional Committee, MTD 11

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Welding General Sectional Committee had been approved by the Metallurgical Engineering Division Council.

This standard proposes a classification and acceptance tests to designate wire-flux combinations in terms of type of flux, mechanical properties of the all-weld metal and the particular type of solid wire to be used in combination.

This standard supersedes IS 7280 : 1974 'Specification for bare wire electrodes for submerged arc welding of structural steels' and IS 3613 : 1974 'Acceptance tests for wire-flux combinations for submerged arc welding of structural steels'. So as to have a complete specification of bare solid wire electrode as well as wire-flux combinations to facilitate the user to select the wire-flux combination on the basis of weld metal property according to this requirement. Although combinations of wires and fluxes supplied by individual manufacturers may have the same grading, the individual wire and fluxes are not interchangeable unless qualified according to this standard. After the publication of this standard IS 7280 : 1974 and IS 3613 : 1974 shall be treated as withdrawn.

It may be noted that the mechanical properties of all weld metal test specimens, used to specify the properties of wire-flux combination according to this standard, may vary from those obtained in production joints because of the differences in welding procedure conditions, such as, electrode size, base metal composition and dimension.

The wire-flux combinations are divided into two categories, namely,

a) for use with the multi-run technique; and
b) for use with the two-run technique, in this case a butt-weld is made with one-run from each side.

Where a manufacturer states that a particular wire-flux combination is suitable for welding with both techniques, both series of tests are to be carried out.

As a rule, better mechanical properties are achieved by the multi-run technique than by the two-run technique. On the other hand, certain wire-flux combinations designed for two-run technique are known to give definitely better results with two-run technique than with the multi-run technique. For this reason, it is proposed that wire-flux combinations should be accepted separately for multi-run and for two-run welding. Multi-run welding will be indicated by 'M' and two-run welding by 'T' in the grade numbers immediately after the impact gradation. The yield stress (in N/mm^2) will form the last digits.

The methods of testing and requirements laid down in this standard are intended primarily for acceptance of wire-flux combinations for automatic and semi-automatic single electrode submerged-arc welding, but they may also be used to a limited extent for acceptance of such combination of other types of submerged-arc welding, such as, multi-wire and multi-power source welding/heat input.

The test requirements laid down in this standard including radiographic quality, are for acceptance tests only and are not intended to be used for design purposes. For this reason the test specimens are not required to be heat-treated before testing (except for low temperature heat treatment to remove hydrogen where specified) regardless whether the welded constructions for which the wire-flux combinations are to be used, are heat-treated or not. Bend test has been included in this standard as it may reveal interdendritic cracks that are not revealed by radiography.

(*Continued on third cover*)

Indian Standard

CLASSIFICATION AND ACCEPTANCE TESTS FOR BARE SOLID WIRE ELECTRODES AND WIRE FLUX COMBINATION FOR SUBMERGED ARC WELDING OF STRUCTRUAL STEEL — SPECIFICATION

1 SCOPE

1.1 This standard contains two sections. Section 1 deals with the classification of bare solid wire electrodes and wire-flux combination for submerged arc welding of structural steel. Section 2 deals with the acceptance tests for wire-flux combination for submerged arc welding of structural steel.

1.2 This standard specifies the requirements of solid filler wire, classifications of wire-flux combinations and all-weld metal properties of each combination in as welded conditions for submerged arc welding of various structural steels (300-450 N/mm^2 yield strength and 400-700 N/mm^2 ultimate tensile strength).

1.3 Any filler wire classified under one particular classification shall not be classified under any other classification of this standard.

1.4 Fluxes may be classified in combination with different wire under more than one classification.

2 REFERENCES

The standards listed below contain provisions, which through reference in this text constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below:

IS No.	*Title*
228 (Parts 1 to 24)	Methods of chemical analysis of steels
812 : 1957	Glossary of terms relating to welding and cutting of metals
1387 : 1993	General requirements for the supply of metallurgical materials (*second revision*)
1608 : 2005	Mechanical testing of metals — Tensile testing (*third revision*)
1757 : 1988	Method for charpy impact test (V notch) for metallic material (*second revision*)
2041 : 2009	Steel plates for pressure vessels used at moderate and low temperature (*third revision*)
2062 : 2006	Hot rolled low, medium and high tensile structural steel (*sixth revision*)
2595 : 2008	Industrial radiographic testing — Code of practice (*second revision*)
11802 : 1986	Method of determination of diffusible hydrogen content of deposited weld metal from covered electrodes in welding mild and low alloy steels

3 TERMINOLOGY

For the purpose of this standard the terms given in IS 812 and the following shall apply.

3.1 Multi-Run Technique — A technique in which a complete weld is deposited in two or more runs from one or each side of a joint. The consecutive runs on each side of a joint may be deposited from separate wires fed concurrently.

3.2 Two-Run Technique — A technique in which a complete weld is deposited in a single-run from each side of a joint, using one or more wires feeding one molten pool.

4 SUPPLY OF MATERIALS

General requirements relating to the supply of solid filler wire and fluxes for submerged arc welding of structural steels shall be as laid down in IS 1387.

SECTION 1 CLASSIFICATION OF BARE SOLID WIRE ELECTRODES AND WIRE-FLUX COMBINATION FOR SUBMERGED ARC WELDING OF STRUCTRUAL STEEL

5 CLASSIFICATION OF WIRE

5.1 The filler wires shall be classified on the basis of their chemical composition.

5.2 In a classification, for example, S-X**,** 'S' indicates solid bare wire. The digit 'X' used as a suffix is equal to twice the amount of the average manganese content of the wire. The presence of molybdenum, silicon, nickel, etc, is indicated by further suffixes like Mo, Si, Ni, etc.

Example

The IS classification 'S-2Mo' means that the solid wire is suitable for automatic and semi-automatic submerged arc welding and it contains 1 percent average content of manganese and an intentional addition of molybdenum as an alloying element.

6 FILLER WIRE MANUFACTURE

The filler wire may be made by any method that will yield a product conforming to the requirements of this specifications.

7 ACCEPTABILITY

7.1 All applicable test requirements of this standard shall be used for acceptance of the products covered by it.

NOTE — Any other test not covered in this specification like the cast, helix and hardness of the wire, tap density, grain size and its distribution, etc, can additionally be included, if mutually agreed to between the supplier and the purchaser. The method of sampling and the number of tests for the additional test shall be as agreed mutually between the supplier and the purchaser.

7.2 Following test to be carried out for determining the acceptability of the wire and flux-wire combination;

a) Chemical composition (for the wire),
b) Radiography,
c) Impact test,
d) Tensile test,
e) Dimensional test (for solid wire), and
f) Diffusible hydrogen test (optional).

8 CHEMICAL COMPOSITION

8.1 The chemical composition of filler wires, when carried out by the method specified in the relevant parts of IS 228 or any other established instrumental/chemical method, should conform to Table 1. In case of dispute the procedure given in IS 228 and its relevant parts shall be the referee method. However, where the method is not given in IS 228 and its relevant parts, the referee method shall be as agreed to between the purchaser and the manufacturer.

8.2 The manufacturer shall carry out the analysis from each cast of steel and, when required by the purchaser, supply a certified cast analysis of a sample of steel from each cast.

8.3 Regarding residual elements, the acceptance limits shall be as agreed to between the manufacturer and the purchaser.

Table 1 Chemical Composition of Filler Wires
(*Clauses* 8.1, 13.2.6 *and* 13.3)

Sl No.	**IS Classification**	**Chemical Composition,** Percent						
		Carbon	Silicon	Manganese	Molybdenum	Nickel	Phosphorus	Sulphur
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	S-1	0.10	0.03	0.40 - 0.60	—	—	0.03	0.03
ii)	S-1Si	0.08 - 0.15	0.10 - 0.40	0.40 - 0.60	—	—	0.03	0.03
iii)	S-2	0.08 - 0.15	0.05 - 0.15	0.80 - 1.20	—	—	0.03	0.03
iv)	S-2Si	0.08 - 0.15	0.15 - 0.40	0.80 - 1.20	—	—	0.03	0.03
v)	S-2Mo	0.08 - 0.15	0.05 - 0.15	0.80 - 1.20	0.45 - 0.60	—	0.03	0.03
vi)	S-2Ni	0.08 - 0.12	0.05 - 0.15	0.80 - 1.20	—	0.80 - 1.20	0.02	0.02
vii)	S-3	0.08 - 0.15	0.05 - 0.25	1.30 - 1.70	—	—	0.03	0.03
viii)	S-3Mo	0.08 - 0.15	0.05 - 0.25	1.30 - 1.70	0.45 - 0.60	—	0.03	0.03
ix)	S-3MoSi	0.08 - 0.12	0.05 - 0.25	1.30 - 1.70	0.45 - 0.60	1.30 - 1.70	0.02	0.02
x)	S-4	0.08 - 0.16	0.05 - 0.25	1.80 - 2.20	—	—	0.03	0.03
xi)	S-4Mo	0.08 - 0.17	0.15 - 0.30	1.80 - 2.20	0.45 - 0.60	—	0.03	0.03
xii)	S-6	0.08 - 0.17	0.20 - 0.30	2.80 - 3.20	—	—	0.03	0.03
xiii)	S-6Mo	0.08 - 0.17	0.15 - 0.30	2.80 - 3.20	0.45 - 0.60	—	0.03	0.03

NOTE — All single values are maximum. The maximum percent of copper in the filler wire due to any coating plus the residual copper content shall be 0.50 *Max*.

9 DIMENSIONS AND TOLERANCES

9.1 The diameters of wire shall be as follows:

1.6, 2.0, 2.4, 3.2, 4.0, 5.0, 6.3 and 8.0 mm

9.2 The tolerance on the diameter of wires shall be ± 0.05 mm.

9.2.1 *The Method of Measuring the Diameter of Wire*

Two measurements at 90° to each other shall be made at one location. Three such pairs of readings at 300 mm from each other shall be taken. Average of all the six readings gives the diameter of the wire.

9.3 The dimensions of the rims and the coils on which wire may be supplied shall be as agreed to between the purchaser and the manufacturer and they shall conform to one of the appropriate dimensions and tolerances given in Tables 2 and 3. The rim shall be designed to operate with respective coil weight.

Table 2 Dimensions and Tolerances for Rims

Sl No.	Internal Diameter mm	Width mm	Net Weight, *Max* Kg
(1)	(2)	(3)	(4)
i)	300^{+15}_{+10}	100^{+15}_{+10}	12.5 ± 1
ii)	300^{+15}_{+10}	100^{+15}_{+10}	12.5 ± 1
iii)	600^{+15}_{+10}	100^{+15}_{+10}	80 ± 5

Table 3 Dimensions and Tolerances for Coils

Sl No.	Internal Diameter mm	Width mm	Net Weight, *Max* Kg
(1)	(2)	(3)	(4)
i)	300 ± 5	100 ± 3	12.5 ± 1
ii)	300 ± 5	100 ± 3	25 ± 2
iii)	600 ± 5	100 ± 3	80 ± 5

10 REELING CONDITIONS

10.1 The wire shall be closely wound in layers on the rim in continuous length and it shall be free from kinks, waves, or sharp bends, so that it is free to unwind without restriction.

10.2 Coils shall be properly bound to prevent entanglement of turns in normal handling. The top end shall be clearly marked for identification. All coils shall contain continuous length of wire made from a single heat or lot.

10.3 Butt weld when present in the wire shall be suitably made so as not to interfere with the uniform and uninterrupted feeding of the wire on automatic and semi-automatic equipment.

11 CONDITION OF WIRE

Filler wires shall have smooth finish and they shall be free from surface imperfections corrosion products, grease, oxide or other foreign matter which would affect adversely the properties of the weld or the operation of the welding equipment.

Temper and surface conditions shall be suitable for uniform uninterrupted feeding on automatic or semi-automatic welding equipment. Unless otherwise specified, the wire shall have a uniform, unbroken well-bonded and smooth copper coating applied on the thoroughly cleaned wire surface.

12 METHOD OF SAMPLING OF WIRE FOR CHEMICAL ANALYSIS

12.1 The location and the method of sampling of wire shall be as agreed to between the manufacturer and the purchaser.

12.2 The area to be sampled shall be obtained from the combined transfers sections of the wire by bundling the wires after cutting into suitable lengths or by folding. The area shall be cleaned by grinding. The sample shall be collected by milling out the area. The total copper content in the wire (coating plus any intentional or residual additions) shall not exceed 0.5 percent by weight.

13 CLASSIFICATION AND ACCEPTANCE OF FLUX

13.1 Classification of flux is based on the mechanical .properties of weld deposit made by using the flux being tested in combination with a particular wire under specific test conditions according to Section 2. The speed, current, voltage, polarity, etc, shall be according to the manufacturer's recommendations.

13.2 The classification of fluxes is divided in to six parts.

13.2.1 The first part gives a symbol indicating the name of the product. The symbol for fluxes shall be the term 'Flux'.

13.2.2 The second part gives a symbol indicating the method of manufacture of the flux. The symbol below indicates the method of manufacture:

a) F — Fused flux,
b) A — Agglomerated flux, and
c) M — Mixed flux (Flux made from crushed slag only or a blend of crushed slag with virgin flux).

The details of method of manufacture, particle size, and current carrying capacity are given in Annex A.

13.2.3 Annexes B and C gives the type of flux and its characteristic chemical constituents.

13.2.4 The third part of the symbol indicates the tensile strength, yield strength, impact strength and percent elongation, when carried out in accordance with IS 1608, as given in Table 4.

Table 4 Symbol For Tensile Strength, Yield Strength, Impact Strength and Percent Elongation

Sl No.	Symbol	Tensile Strength N/mm^2	Yield Strength N/mm^2	Impact Strength J	Percent Elongation
(1)	(2)	(3)	(4)	(5)	(6)
i)	For multi pass welds:				
	a) M1	400 - 600	300	35	22
	b) M2	460 - 650	350	40	22
	c) M3	520 - 700	450	47	22
ii)	For two-run welds:				
	a) T1	400 - 600	300	35	22
	b) T2	500 - 650	350	40	22
	c) T3	550 - 700	450	47	22

13.2.5 The fourth part indicates symbol and temperature of testing for determining impact properties of all weld metal, when carried out in accordance with IS 1757 as given below in Table 5

Table 5 Symbol and Temperature for Determining Impact Properties

Sl No.	Symbol	Temperature °C ±1
(1)	(2)	(3)
i)	1	Room temperature (20°C approximately)
ii)	2	0
iii)	3	– 20
iv)	4	– 40

13.2.6 The fifth part gives a symbol indicating the chemical composition of the wire-electrode used. The symbol shall be according to Table 1.

13.2.7 The sixth part is optional and applicable for hydrogen controlled flux producing a weld metal with a low content of diffusible hydrogen. The symbol indicates the all-weld metal hydrogen content determined according to IS 11802. The symbol shall be as given below in Table 6.

Table 6 Symbol for Diffusible Hydrogen

Sl No.	Symbol	Diffusible Hydrogen Content, *Max* (ml/100 g Deposited Weld Metal)
(1)	(2)	(3)
i)	H- 5	5
ii)	H-10	10
iii)	H-15	15

13.2.7.1 If a low hydrogen weld metal is necessary, in view of the metal to be welded, the flux manufacturer should be consulted for details of re-drying condition (if any) specific to the flux.

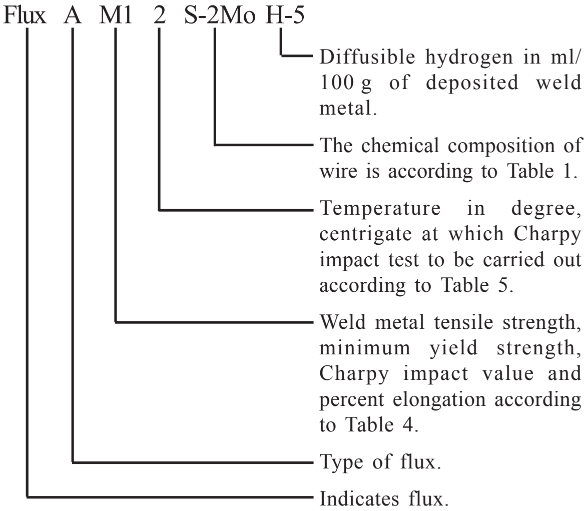
For the purpose of certifying compliance with diffusible hydrogen requirements, the reference atmospheric condition shall be an absolute humidity of 1.43 g of water/kg of dry air at the time of welding. The actual atmospheric conditions shall be reported along with the average value for the test. When absolute humidity equals or exceeds the reference condition at the time of preparation of the test assembly, the test shall be acceptable as demonstrating compliance with the requirements of this specification provided the actual test results satisfy the diffusible hydrogen requirements for the applicable symbol.

13.2.7.2 *Weld metal composition*

The weld metal composition may be as agreed to between the purchaser and the supplier.

13.3 Example of Flux Wire Classification

A flux for submerged arc welding classified as below shall have the following meaning:



Flux A M1 2 S-2Mo H-5

Diffusible hydrogen in ml/100 g of deposited weld metal.

The chemical composition of wire is according to Table 1.

Temperature in degree, centrigate at which Charpy impact test to be carried out according to Table 5.

Weld metal tensile strength, minimum yield strength, Charpy impact value and percent elongation according to Table 4.

Type of flux.

Indicates flux.

Flux A M1 2 S-2 Mo H-5

Symbol	*Description*
Flux	Product is a submerged arc welding flux.
A	Flux is agglomerated.
M1	Weld metal has tensile strength of 400-600 N/mm^2, minimum yield strength 300 N/mm^2, Charpy impact value of 35 J and percent elongation is 22 minimum.
2	Charpy impact test to be carried out at 0°C.
S-2 Mo	Chemical composition of wire is according to Table 1.
H-5	Diffusible hydrogen 5 ml/100 g deposited weld metal.

13.4 Radiography

13.4.1 Radiographic testing shall be carried out according to IS 2595. The soundness of the weld metal, meets the requirements of this specification, if the radiograph satisfies as specified in **13.4.2** to **13.4.7**.

13.4.2 No cracks, no incomplete fusion, and no incomplete penetration.

13.4.3 No slag inclusions longer than 8 mm or no groups of slag inclusions in line that have an aggregate length greater than 25 mm in a 300 mm length except when the distance between the successive inclusions exceeds 6 times the length of the longest inclusions in the group.

13.4.4 No rounded indications in excess of those indicated below:

a) *Assorted rounded indications:*
   1) Size permitted — .4 -1.6 mm, and
   2) No. of indications permitted in 150 mm of weld is 18 subject to the following,
      i) Large 1.2 - 1.6 mm — 3 No. permitted;
      ii) Medium 0.8 - 1.2 mm — 5 No. permitted, and
      iii) Small 0.4 - 0.8 mm — 10 No. permitted.

b) *Large rounded indications:*
   1) Size permitted — 1.2 -1.6 mm, and
   2) No. of indications permitted in 150 mm of weld is 8.

c) *Medium rounded indications:*
   1) Size permitted — 0.8 -1.2 mm, and
   2) No. of indications permitted in 150 mm of weld is 15.

d) *Small rounded indications:*
   1) Size permitted — 0.4 - 0.8 mm,
   2) No. of indications permitted in 150 mm of weld is 30,
   3) Rounded indications smaller than 0.4 mm shall be discarded, and
   4) Largest dimensions of the indications (including any tail) is the size of the indication.

13.4.5 In evaluating the radiograph, 25 mm of the weld on each end of the test assembly shall be disregarded.

13.4.6 A rounded indication is an indication (on the radiograph) whose length is not more than 3 times its width. Rounded indications may be circular, or irregular in shape, and they may have tails. The size of a rounded indication is the largest dimension of the indication, including any tail that may be present.

13.4.7 Indications whose largest dimension does not exceed 0.4 mm shall be disregarded. Test assemblies with indications larger than the large indications permitted as indicated above do not meet the requirements of this specification.

14 FLUX MANUFACTURE

Fluxes shall be manufactured by any method that will yield a product conforming to the respective classification requirements.

15 ACCEPTABILITY AND TESTING OF FLUX

All the test requirements of this specification should be used as a basis for acceptance of the products covered by the specification.

16 TEST REQUIREMENTS AND METHOD OF TESTING

In order to classify a flux under this specification, the tests as mentioned in Section 2, to demonstrate its usability, soundness, mechanical properties of the deposited metal with multi-run and/or two-run technique shall be conducted.

17 RE-TESTS

Where any test specimen fails to fulfill the test requirements, twice the number of test specimens, shall be made further from the same batch for the test in which the failure occurred. The .product shall not be accepted as having passed that test unless all the additional test results conform to the requirements prescribed for that test.

18 TECHNICAL DELIVERY CONDITION

The flux shall be granular in nature and should be capable of free flow through the flux feed system of a standard welding equipment but need not otherwise have a specific particle size or shape. The particle size distribution shall be uniform and consistent in the different packaging unit.

The fluxes shall be suitably packaged to ensure against damage during transportation and storage under normal condition.

A flux in original unopened package shall withstand storage under normal condition for at least six months without affecting its welding characteristics or the weld properties.

If any special packaging is required by the purchaser, the same should be according to mutual agreement between the purchaser and the manufacturer.

SECTION 2 ACCEPTANCE TESTS FOR WIRE-FLUX COMBINATION FOR SUBMERGED ARC WELDING OF STRUCTURAL STEEL

19 GENERAL

19.1 This section covers acceptance tests for wire-flux combinations for submerged-arc welding of carbon steel and medium tensile steel having a tensile strength of not more than 700 N/mm^2 and a sulphur and phosphorous content of not greater than 0.06 percent each.

19.2 Clause **21** specifies requirements for acceptance tests for wire-flux combinations for use with the multi-run technique which give on all-weld metal tests, a tensile strength within the range 400-600 N/mm^2 (41-61 kgf/mm^2) and the yield stress not less than 300 N/mm^2 (31 kgf/mm^2). The elongation shall not be less than 22 percent.

19.3 Clause **22** specifies requirements for acceptance tests for wire-flux combinations for use with multi-run technique which give on all-weld metal tests, a tensile strength within the range 460-650 N/mm^2 (47-66 kgf/mm^2) and the yield stress not less than 350 N/mm^2 (36 kgf/mm^2). The elongation shall not be less than 22 percent.

19.4 Clause **23** specifies requirements for acceptance tests for wire-flux combinations for use with the multi-run technique which give on all-weld metal tests, a tensile strength within the range 520-700 N/ mm^2 (53-71 kgf/ mm^2) and the yield stress not less than 450 N/mm^2 (46 kgf/mm^2). The elongation shall not be less than 22 percent.

19.5 Clause **24** specifies requirements for acceptance tests for wire-flux combinations for use with the two-run technique which give on longitudinal weld tests, a tensile strength within the range 400-600 N/mm^2 (41-61 kgf/mm^2) and the yield stress shall not be less than 300 N/mm^2 (31 kgf/mm^2). The elongation shall not be less than 22 percent.

19.6 Clause **25** specifies requirements for acceptance tests for wire-flux combinations for use with the two-run technique which give on longitudinal weld tests, a tensile strength within the range 500-650 N/mm^2 (51-66 kgf/ mm^2) and the yield stress shall not be less than 350 N/mm^2 (36 kgf/mm^2). The elongation shall not be less than 22 percent.

19.7 Clause **26** specifies requirements for acceptance tests for wire-flux combinations for use with the two-run technique which give on longitudinal weld tests, a tensile strength within the range 550-700 N/mm^2 (56-71 kgf/mm^2) and the yield stress shall not be less than 450 N/mm^2 (46 kgf/mm^2). The elongation shall not be less than 22 percent.

20 MATERIAL

20.1 Parent Metal

The parent metal used for test plates shall conform to the requirements specified in Annex D.

20.2 Bare Wire Electrode

Bare wire for submerged-arc welding shall conform to Section 1.

20.3 Fluxes

Fluxes shall be classified and coded in accordance with Section 1.

20.4 Fluxes shall be granular in nature and capable of free flow through the flux feeding tubes, valves and nozzles of standard welding equipment.

20.5 Sizing shall be uniform to the extent that flux of one container taken at random will be similar for each grade of flux.

20.6 Packing and Storage

Flux shall be packed in moisture proof container and shall be protected from damage during transportation and storage. When stored, the flux should be kept in its original container in a dry store-room and under such condition the flux shall, for a period of at least six months, be capable of giving results similar to those it would have given on the date of its dispatch from the manufacturer.

20.7 Test Requirements

The wire and flux combinations shall be capable of complying in all respects with the test requirements of this standard. Wire-flux combinations suitable for use on both ac and dc (electrode positive or negative) should preferably be tested on ac but in all cases the current used in the tests shall be reported.

20.8 Initial Tests

These comprise the initial tests to which each type of wire and flux shall be subjected and it is implicit in the manufacturer's certificate that the wires and fluxes in current production are capable of satisfying the whole of test requirements.

20.8.1 *Initial Tests for Multi-Run Technique*

When approval for use with multi-run technique is required, all-weld metal and butt-weld tests are required to be carried out in accordance with **20.9** and **20.9.5**.

20.9 All-Weld Metal Tests

20.9.1 *Preparation of Weld Assembly*

20.9.1.1 Tensile and impact tests are to be made from the metal deposited from the wire-flux combinations.

20.9.1.2 An all-weld metal test assembly is to be prepared in the down hand position as shown in Fig. 1 and the specimen shall be prepared as shown in Fig. 2.

20.9.1.3 The bevelling of the plate edges shall be carried out by machining or mechanized gas cutting. Oil, dirt, rust and scale shall be removed from the fusion faces before welding. The surface of the backing strip shall be free from rust and scale. The backing strip shall be tack welded to the 20 mm plates.

20.9.1.4 The plates shall be preset so that they are approximately flat after the welding operation has been completed.

20.9.1.5 The welding shall be carried out with that combination of wire and flux which is to be approved. It should be ensured that the wire is clean and free from oil, grease, paint and rust and that the flux is dried according to manufacturer's recommendation before use.

20.9.1.6 The welding condition (current, voltage and rate of travel) shall be in accordance with the recommendations of the manufacturer and conform to normal good welding practice for multi-run technique.

20.9.1.7 The welding current may be either ac or dc (electrode positive or negative) according to the recommendations of the manufacturer. If both are permitted ac shall be used for the tests.

20.9.1.8 It is advisable to start and end welding on run-on and run-off plates tack welded to the test plates. After completion of each run the flux and welding slag is to be removed. Between each run the test piece is to be left in still air until it has cooled to 250°C (controlled by test colour or other adequate methods) the temperature being taken in the centre of the weld, on the surface of the seam. The thickness of the layer is not to be less than the diameter of the wire but not less than 4 mm.

20.9.1.9 The welded test piece shall be cut as shown in Fig. 2.

20.9.2 *X-Ray Examination*

It is recommended that the welded assembly be subjected to radiographic examination to ascertain any welding defects in the weld prior to testing. The backing strip/plate shall be removed by machining before conducting radiographic examination. *See* **13.4** for test evaluation.

20.9.3 *Tensile Test*

20.9.3.1 Two tensile test pieces shall be cut from the test pieces according to the indications given in Fig. 2 and Fig. 3 and machined to the dimensions given in Fig. 4, care being taken that the longitudinal axis coincides with the centre of the weld and the mid-thickness of the plates.

20.9.3.2 The test pieces for tensile test shall be heated between 200°C and 250°C for a period of 16 h for hydrogen removal, prior to testing. The tensile test shall be carried out at the ambient temperature according to IS 1608.

20.9.3.3 Each test specimen shall fulfil the requirements of deposited metal tensile test.

20.9.4 *All-Weld Metal Impact Test*

20.9.4.1 The impact test specimens shall be of the Charpy V-notch type.

20.9.4.2 Three impact test specimens shall be cut from the test piece as shown in Fig. 2 and Fig. 5, care being taken that their longitudinal axis is perpendicular to the weld and taken from mid-thickness of the plates. The dimensions of the test specimens are as given in Fig. 6.

20.9.4.3 The notch shall be positioned in the centre of the weld and shall be cut in the face of test specimens perpendicular to the surface of the plates as shown in Fig. 5. The test shall be carried out in accordance with IS 1757.

20.9.5 *Multi-Run Butt-Weld Tests*

20.9.5.1 *Preparation of weld assembly*

20.9.5.1.1 A butt-weld assembly as shown in Fig. 7 shall be prepared in the down head position by welding together two 20-mm plates not less than 150 mm in width and of sufficient length (approximately 600 mm) to allow the cutting out of test specimens of the prescribed number and size.

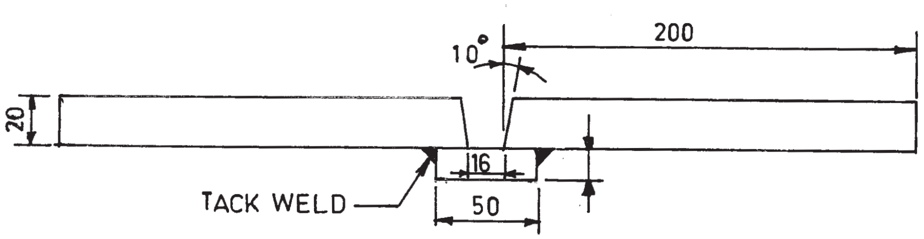
20.9.5.1.2 The plate edges shall be prepared to form a single V-joint, the included angle between the fusion faces being 60° and the root face being 4 mm. The root gap shall be 1 mm maximum. The bevelling of the plate edges shall be carried out by machining or mechanized gas cutting. In the latter case, any remaining scale shall be removed from the bevelled edges.

20.9.5.1.3 The plates shall be so preset that they are approximately flat after the welding operation has been completed. The welding shall be carried out by the multi-run technique and the welding conditions (current, voltage and speed) shall be in accordance with the recommendations of the manufacturer and shall conform to normal good welding practice for multi-run technique.

20.9.5.1.4 Wire-flux combinations suitable for use on both ac and dc (electrode positive or negative) should preferably be tested on ac.

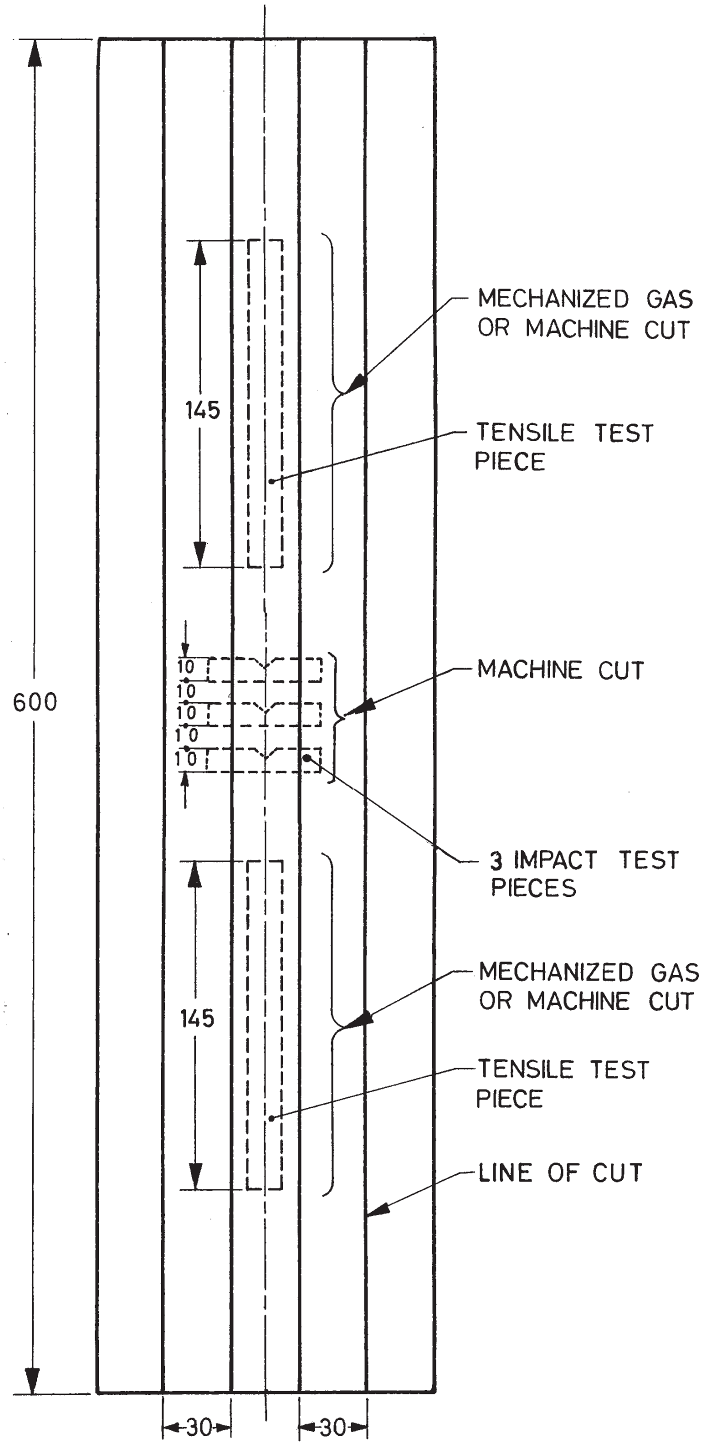
20.9.5.1.5 The back sealing run shall be applied in the down head position after removing the root run to clean metal.

20.9.5.1.6 After being welded, the test piece shall not be subjected to any heat treatment.



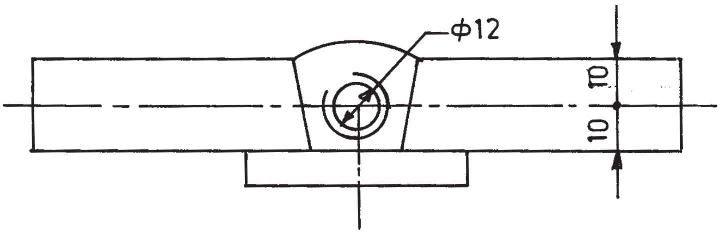
All dimensions in millimetres.

FIG. 1 DIMENSIONS OF ALL-WELD METAL TEST ASSEMBLY



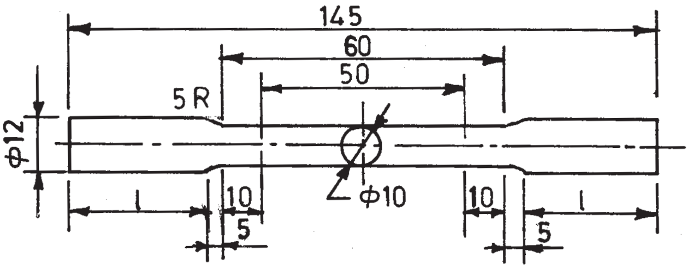
All dimensions in millimetres.

FIG. 2 DIMENSIONS OF ALL-WELD METAL TEST PIECES



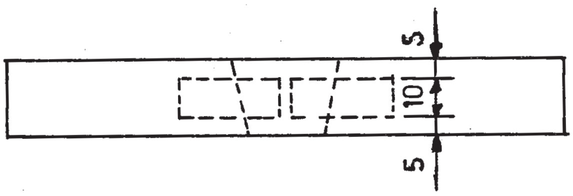
All dimensions in millimetres.

FIG. 3 LOCATION OF THE ALL-WELD METAL TENSILE TEST SPECIMEN



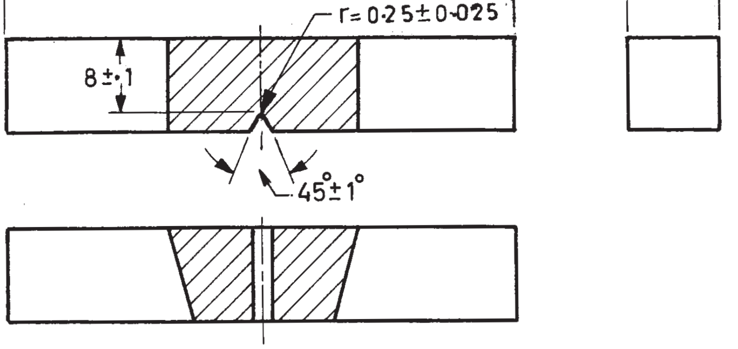
All dimensions in millimetres.

FIG. 4 DIMENSIONS OF THE TENSILE TEST SPECIMEN TO BE MACHINED



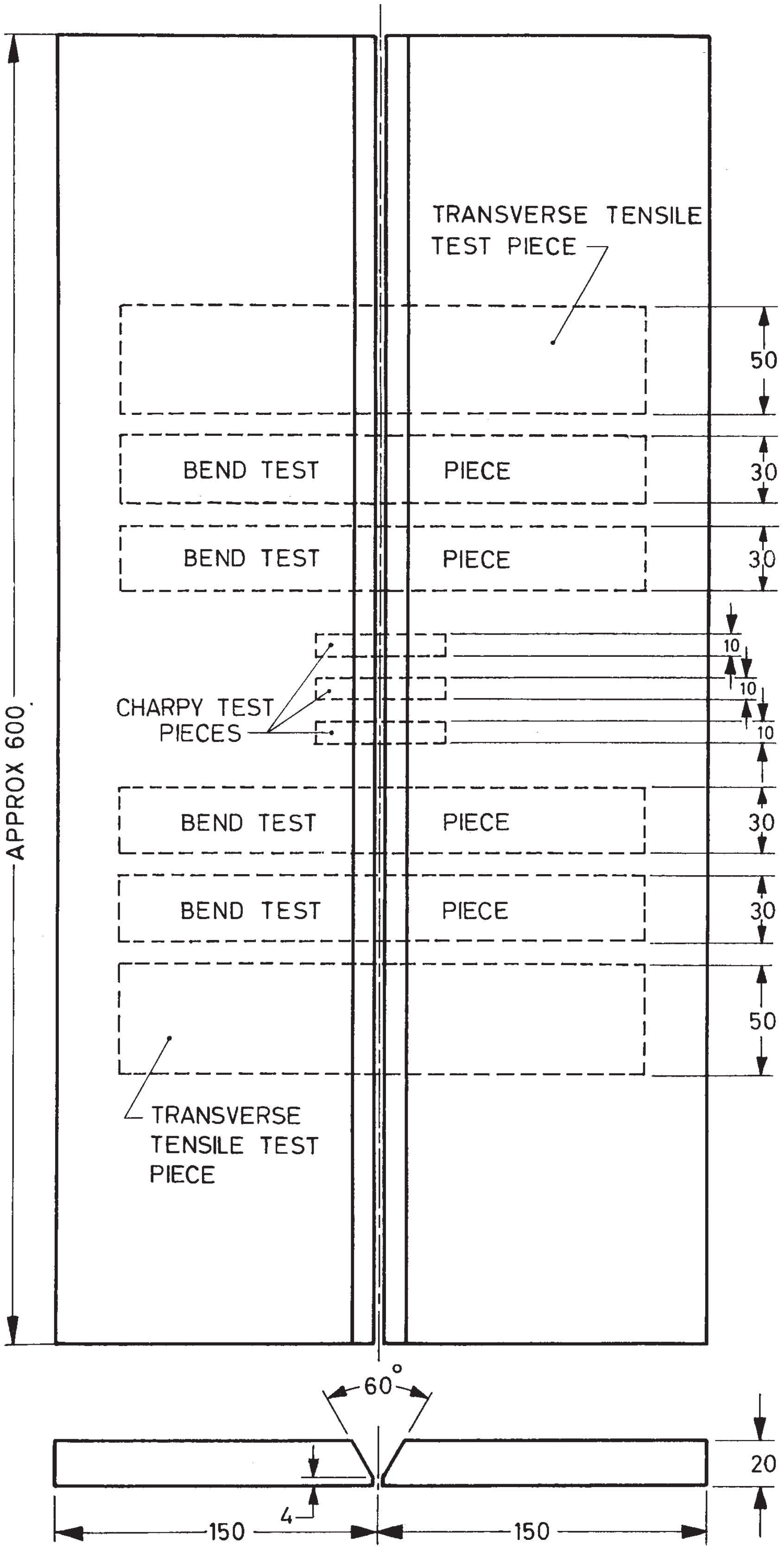
All dimensions in millimetres.

FIG. 5 LOCATION OF THE ALL-WELD METAL IMPACT TEST SPECIMEN



All dimensions in millimetres.

FIG. 6 DIMENSIONS OF THE IMPACT TEST SPECIMEN TO BE MACHINED



All dimensions in millimetres.

FIG. 7 METHOD OF CUTTING TEST SPECIMENS FROM A BUTT-WELD ASSEMBLY

20.9.5.1.7 It is recommended that the test piece shall be subjected to radiographic examination to ascertain any defects in the weld prior to testing.

20.9.5.1.8 The test piece shall then be cut to form two transverse tensile, two face bend, two root bend and three Charpy V-notch impact specimens as shown in Fig. 7.

20.9.6 *Butt-Weld Tensile Tests*

Two transverse tensile specimens shall be machined to the dimensions as given in Fig. 8. The upper and lower surfaces of the weld shall be filed, ground or machined flush with the surface of the plate. Where the surfaces of the plate are not level with each other, the metal may be cut away to bring them approximately level, provided that the thickness of the plate is not reduced by more than a total of 1 mm. The tensile strength of each specimen shall not be less than the specified values prescribed in **21** to **26.**

20.9.7 *Butt-Weld Bend Tests*

20.9.7.1 Four transverse bend test specimens, 30 mm in width, shall be taken from the welded assembly. The upper and lower surfaces of the weld shall be filed, ground or machined flush with the surface of the plate and the sharp corners of the specimens shall be capable of being bent through an angle of 120° without fracture over a former having a diameter three times the thickness of the specimen. Two specimens shall be tested with the face of the weld in tension and two specimens with the root of the weld in tension. Where the surfaces of the plates are not level with each other, the metal may be cut away to bring them approximate level, provided that the thickness of the plate is not reduced by more than a total of 1 mm.

20.9.7.2 The test specimens shall be considered as complying with the test, if on completion of the test, no crack or defect at the outer surface of the test specimen is greater than 3 mm when measured across the specimen or 1.5 mm when measured along the length of the specimen. Premature failure at the corners of the specimens shall not be considered cause of failure.

20.9.8 *Butt-Weld Impact Test*

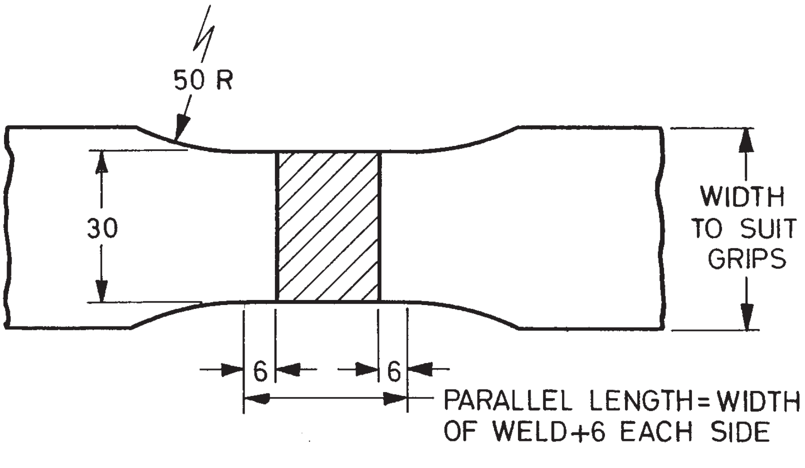
Three Charpy V-notch impact test pieces shall be machined from the test assembly. The test specimens shall be prepared as shown in Fig. 5 and Fig. 6. The test pieces shall be cut with their longitudinal axes perpendicular to the weld. The test specimens shall be taken from the middle of the plate thickness with the notch perpendicular to the surface of the plate. The average value of the Charpy impact tests shall be given in **21** to **26**.

20.9.9 *Initial Tests for Two-Run Technique*

20.9.9.1 *Preparation of weld assembly*

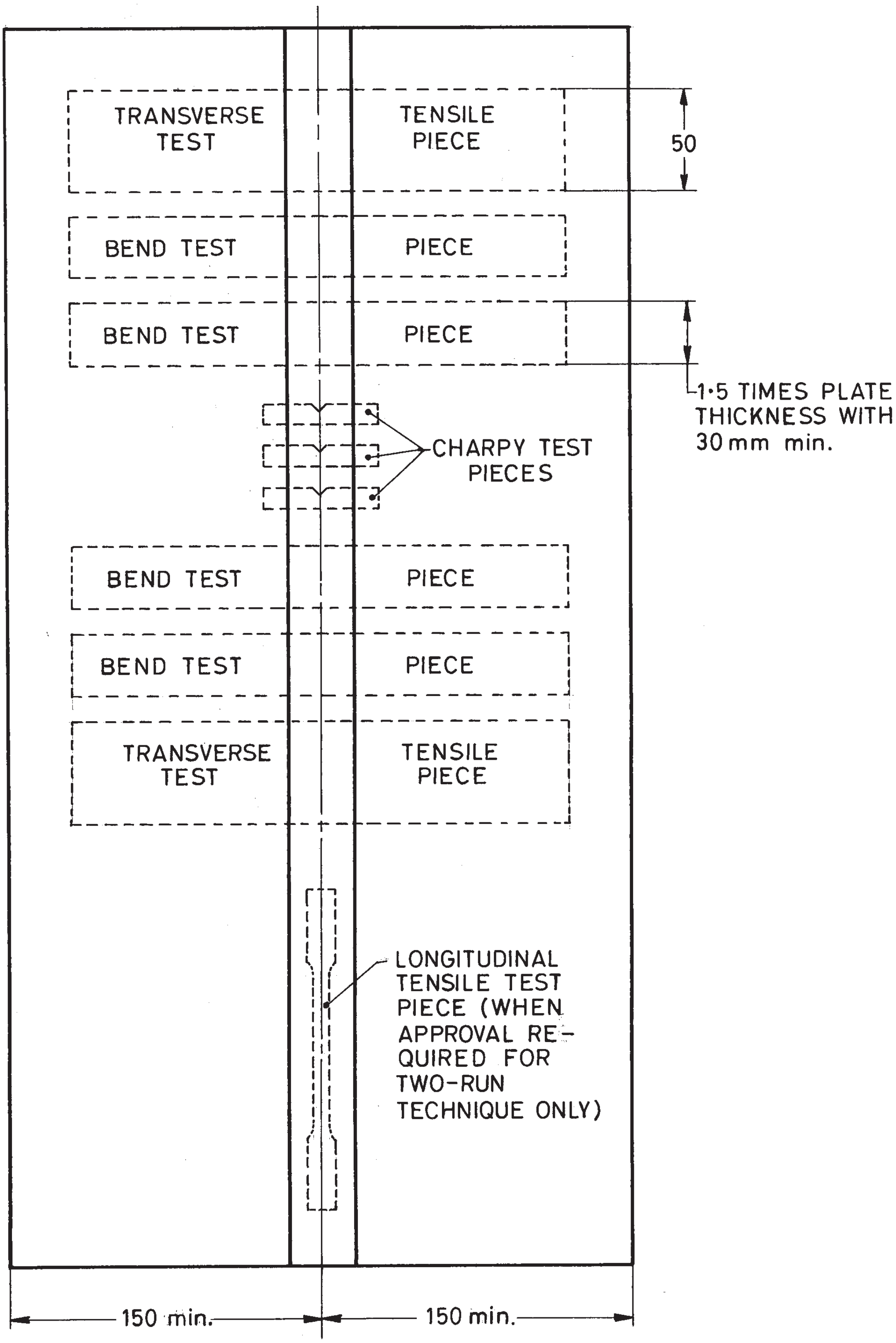
20.9.9.2 Two welded test pieces shall be prepared, one each with 12 to 15 mm and 20 mm plate thickness as shown in Fig. 9 using the plate material as specified in Annex D. Where the flux is to be employed only for two-run technique on plate thickness exceeding 20 mm up to and including 36 mm, test on 36 mm plate as indicated in Fig.10 and Fig. 11 shall be carried out. All three tests are to be carried out where the flux is to be qualified for plate thicknesses up to 36 mm. The maximum diameter of the wire and edge preparation to be used shall be in accordance with Fig.10. Small deviation in the edge preparation may be allowed, if recommended by the manufacturer.

20.9.9.3 The bevelling of the plate edges shall be performed by machining or mechanized gas cutting. In the latter case, any remaining scale shall be removed from the bevelled edges. The root gap should not exceed 1 mm. Each butt-weld shall be welded in two-run, one from each side, using current



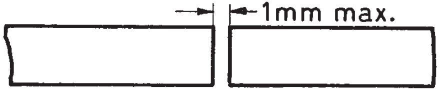
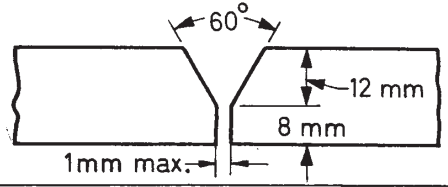
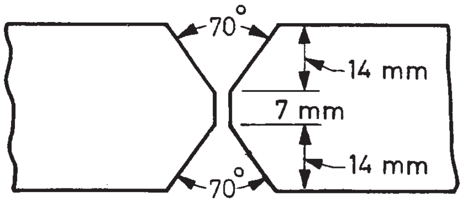
All dimensions in millimetres.

FIG. 8 BUTT-WELD TENSILE TEST SPECIMEN



All dimensions in millimetres.

FIG. 9 METHOD OF CUTTING TEST PIECE FROM ASSEMBLY FOR TWO-RUN TECHNIQUE

PLATE THICKNESS mm	GROOVE PREPARATION	MAXIMUM WIRE DIAMETER mm
12 – 15		5·0
20		6·3
36		8·0

All dimensions in millimetres.

FIG. 10 WIRE DIAMETER FOR EDGE PREPARATION OF PLATES 12-15, 20 AND 36 mm THICK

voltages and travel speeds in accordance with the recommendations of the manufacturer and normal good welding practice. After completion of the first run, the flux and welding slag shall be removed and the assembly shall be left in still air until it has cooled to 100°C, the temperature being taken in the centre of the weld, on the surface of the seam. After being welded, the test pieces shall not be subjected to any heat treatment. The two discard ends (40 mm, *Min*) shall be prepared and etched to check for interlocking of welds.

20.9.10 *X-Ray Examination*

It is recommended that the welded test piece be subjected to radiographic examination to ascertain any defects in the weld prior to testing. *See* **13.4** for test evaluation.

20.9.11 *Butt-Weld Tensile Tests*

Two transverse tensile specimens shall be machined to the dimensions as given in Fig. 8. The upper and lower surfaces of the weld shall be filed, ground or machined flush with the surfaces of the plates. Where the surfaces of the plates are not level with each other, the metal may be cut away to bring them approximately level, provided that the thickness of the plate is not reduced by more than a total of 1 mm. The tensile strength of each specimen shall not be less than the specified values in the respective sections.

20.9.12 *Longitudinal Weld Tensile Test*

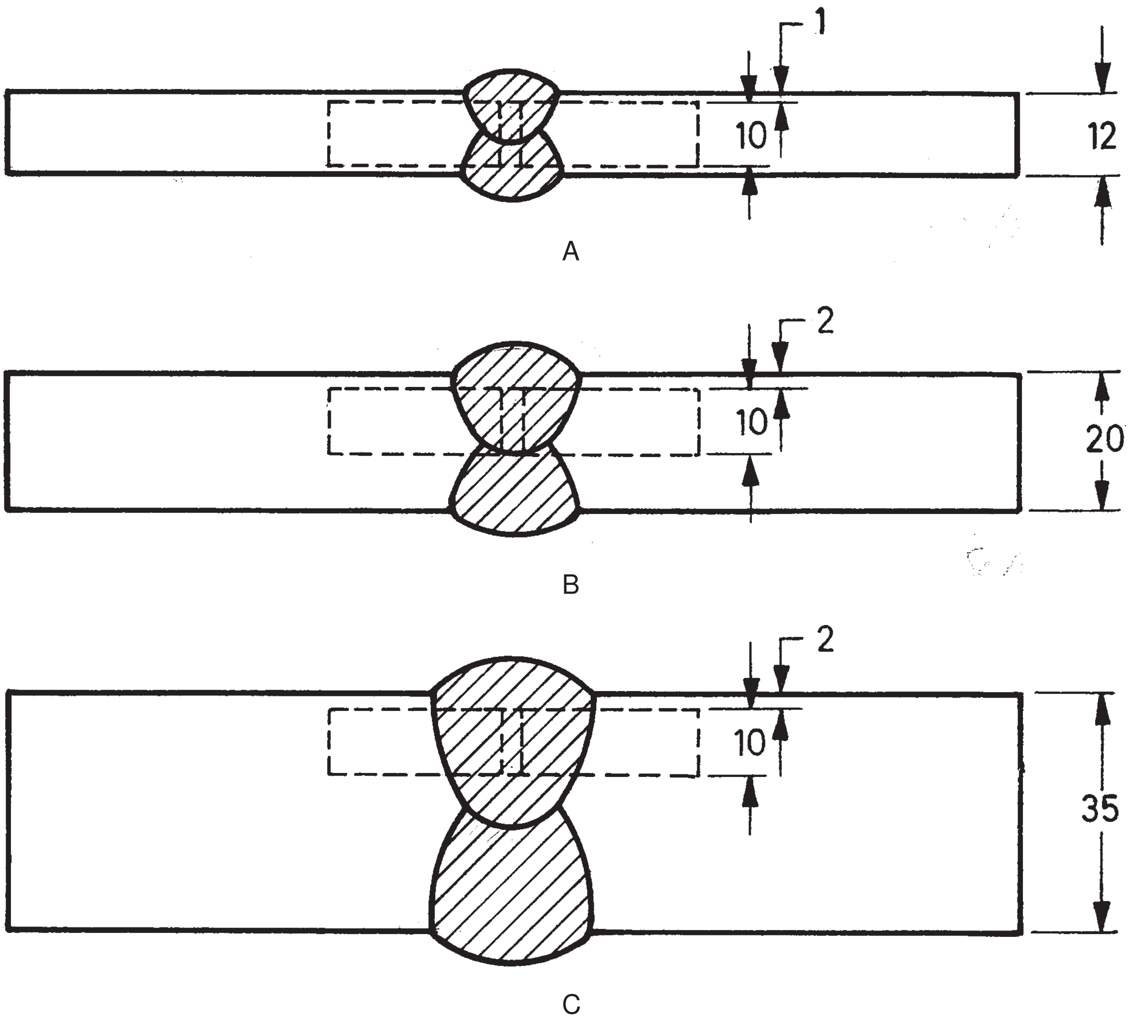
When a wire-flux combination has to be approved for two-run welding only, one additional longitudinal tensile test specimen shall be taken out from the positions as shown in Fig. 9 from each test piece and machined according to Fig. 4. The longitudinal axis shall coincide with the centre of the weld about 7 mm below the plate surface on the side from which the second run is made. The test specimen shall be heated between 200°C and 250°C for a period of 16 h for hydrogen removal, prior to testing. The tensile strength of each test specimen shall not be less than the specified values in the respective sections.

20.9.13 *Butt-Weld Bend Tests*

Four transverse bend test specimens, 30 mm in width, shall be taken from the test piece. The upper and lower surfaces of the weld shall be filed, ground or machined flush with the surface of the plate and the sharp corners of the specimens rounded to a radius not exceeding 2 mm. The test specimens shall be capable of being bent through an angle of 120° without fracture over a former having a diameter three times the thickness of the specimen. Two specimens shall be tested with the face of the weld in tension and two specimens with the root of the weld in tension. Where the surfaces of the plates are not in level with each other, the metal may be cut away to bring them approximately level, provided that the thickness of the plate is not reduced by more than a total of 1 mm.

20.9.14 *Butt-Weld Impact Tests*

Charpy V-notch impact tests shall be carried out on three test specimens from each welded test piece. The position of the test specimen and of the notch in relation to the welded seam is shown in Fig. 11.



All dimensions in millimetres.

FIG. 11 LOCATIONS OF BUTT-WELD IMPACT TEST SPECIMENS

The average of the three impact values shall not be less than that specified in the respective section.

20.10 Periodic Check Tests

Periodic check tests consist of a selection of specified tests and they shall be repeated at intervals not exceeding 12 months to provide evidence that the wire and flux combinations continue to possess the properties recorded in the initial tests. Samples of approved wire-flux combinations shall be subjected to at least the following tests annually.

20.10.1 *Periodic Check Tests for Multi-Run Welding*

20.10.1.1 *All-weld metal test*

Two tensile and three impact tests shall be carried out on specimens taken from the all-weld metal test piece.

20.10.1.2 *Periodic check test for two-run welding*

20.10.1.3 Two transverse tensile, four bend and three impact tests shall be carried out on transverse specimens taken from a 20-mm V-butt-weld test piece.

20.11 X-Ray Examination

Only when a wire-flux combination is approved for application of pressure vessels, in addition to the prescribed tests, the test pieces shall be subjected to a radiographic examination to ascertain any defect in weld.

20.12 Production Control Tests

By means of suitable system of control and testing, the manufacturer shall ensure that the wires and fluxes currently provided would meet the same requirements as those approved in the initial tests. The result of the production control tests and the dates of manufacture shall be capable of being traced from the batch number.

20.13 Additional Tests

Subject to agreement with the manufacturer, the purchaser may request for additional tests to be made or certificates to be provided for each batch of wire-flux combination supplied. If so, the tests and batch definition shall be as agreed to between the purchaser and the supplier.

20.14 Re-Tests

When any test specimen fails to satisfy the test requirement, twice the number of specimens specified for initial or periodic check tests shall be prepared using wire and fluxes preferably from the same batches and submitted to the tests in which failure occurred. Provided that the tests are satisfactory, the wire and the flux may be accepted as having passed the test.

21 MULTI-RUN TECHNIQUE: ALL-WELD METAL TENSILE STRENGTH 400-600 N/mm^2 (41-61 kgf/mm^2), MINIMUM YIELD STRESS 300 N/mm^2 (31 kgf/mm^2), NOT COVERED BY 22 AND 23

21.1 All-Weld Tensile Tests

The tensile strength of each specimen shall be within the range 400-600 N/mm^2 (41-61 kgf/mm^2) and the yield stress not less than 300 N/mm^2 (31 kgf/mm^2). The elongation shall be not less than 22 percent.

21.2 All-Weld Impact Tests

The average of the three impact values shall not be less than the following :

Grade	*Average Impact Values, Min*		*Testing Temperature* °C
	J	kgf/m	
M11	35	3.5	(Room Temp) 20 Approx
M12	35	3.5	0 ± 1
M13	35	3.5	– 20 ± 1
M14	35	3.5	– 40 ± 1

The results of the impact tests shall be assessed as specified in **21.2.1.**

21.2.1 The average $\overline{x}_3$ of the results of the three tests shall be assessed as follows:

$\overline{x}_3$ J	*Assessment*
Up to and including 30	Requirement not fulfilled
Including and over 35	Requirement fulfilled

If the value of $\overline{x}_3$ lies between 30 J and 35 J, three additional specimens shall be prepared and tested, and the results added to those previously obtained to form a new average $\overline{x}_6$. If the value of $\overline{x}_6$ is 35 J or above, the wire-flux combination shall be deemed to have fulfilled the requirements.

If the value of $\overline{x}_6$ is less than 35 J, further six specimens shall be prepared using the same batch of wire and fluxes, if possible and tested, and the results added to the previous value of $\overline{x}_6$ to form a new average $\overline{x}_{12}$ the value of which shall not be less than 35 J.

21.3 Chemical Composition

The percentage contents of carbon, manganese, silicon, sulphur and phosphours in the deposited weld metal from all-weld test piece may be reported. The sulphur and phosphorus content shall not exceed 0.05 percent each.

21.4 Transverse Tensile Tests

Two transverse tensile specimens shall be prepared in accordance with the method specified in **20.9.6**.

The tensile strength of each specimen shall not be less than 400 N/mm^2 (41 kgf/mm^2).

21.5 Transverse Bend Test

Four transverse bend specimens shall be prepared and tested in accordance with the method specified in **20.9.7**.

21.5.1 Each test specimen satisfies, if bent through an angle of 120° over a former having a diameter equal to three times the thickness of the specimens, no crack or defect at the outer surface of the specimens greater than 3 mm measured across the specimen or 1.5 mm along the length of the specimen. Premature failure at the corners of the specimens shall not be considered cause of failure.

22 MULTI-RUN TECHNIQUE: ALL-WELD METAL TENSILE STRENGTH 400-600 N/mm^2 (41-61 kgf/mm^2), MINIMUM YIELD STRESS 300 N/mm^2 (31 kgf/mm^2), NOT COVERED BY 21 OR 23

22.1 All-Weld Tensile Tests

The tensile strength of each specimen shall be within the range 460-650 N/mm^2 (47-66 kgf/mm^2) and the yield stress not less than 350 N/mm^2 (36 Kgf/mm^2). The elongation shall be not less than 22 percent.

22.2 All-Weld Impact Tests

The average of the three impact values shall not be less than the following:

Grade	*Average Impact Value, Min*		*Testing Temperature* °C
	J	kgf/m	
M21	40	4.0	(Room Temp) 20 Approx
M22	40	4.0	0 ± 1
M23	40	4.0	– 20 ± 1
M24	40	4.0	– 40 ± 1

22.2.1 The average $\overline{x}_3$ of the results of the three tests shall be assessed as follows:

$\overline{x}_3$	*Assessment*
J	
Up to and including 34	Requirement not fulfilled
Including and over 40	Requirement fulfilled

If the value lies between 34 J and 40 J, three additional specimens shall be prepared and tested, and the results added to those previously obtained to form a new $\overline{x}_6$. If the value of $\overline{x}_6$ is 40 J or above, the wire-flux combination shall be deemed to have fulfilled the requirements.

If the value of $\overline{x}_6$ is less than 40 J, further six specimens shall be prepared using the same batch of wire and fluxes, if possible and tested, and the results added to the previous value of $\overline{x}_6$ to form a new average $\overline{x}_{12}$ the value of which shall not be less than 40 J.

22.3 Chemical Composition

The percentage contents of carbon, manganese, silicon, sulphur and phosphorus in the deposited weld metal from the all-weld test piece may be reported. The sulphur and phosphorus content shall not exceed 0.05 percent each.

22.4 Transverse Tensile Tests

Four transverse bend specimens shall be prepared and tested in accordance with the method specified in **20.9.6**.

The tensile strength of each specimen shall be not less than 500 N/mm^2 (51 kgf/mm^2).

22.5 Transverse Bend Test

Four transverse bend specimens shall be prepared and tested in accordance with the method specified in **20.9.7**.

Each test specimen satisfies, if bent through an angle of 120° over a former having a diameter equal to three times the thickness of the specimen, no crack or defect at the outer surface of the specimen is greater than 3 mm measured across the specimen or 1.5 mm along the length of the specimen. Premature failure at the corners of the specimens shall not be considered cause of failure.

23 MULTI-RUN TECHNIQUE: ALL-WELD METAL TENSILE STRENGTH 520-700 N/mm^2 (53-71 kgf/mm^2), MINIMUM YIELD STRESS 450 N/mm^2 (46 kgf/mm^2), NOT COVERED BY 21 OR 22

23.1 All-Weld Tensile Test

The tensile strength of each specimen shall be within the range 520-700 N/mm^2 (53-71 kgf/mm^2) and the yield stress not less than 450 N/mm^2 (46 kgf/mm^2). The elongation shall be not less than 22 percent.

23.2 All-Weld Impact Test

The average of the three impact values shall not be less than the following:

Grade	*Average Impact Values, Min*		*Testing Temperature* °C
	J	kgf/m	
M31	47	4.7	(Room Temp) 20 Approx
M32	47	4.7	0 ± 1
M33	47	4.7	– 20 ± 1
M34	47	4.7	– 40 ± 1

23.2.1 The average $\overline{x}_3$ of the results of the three tests shall be assessed as follows:

$\overline{x}_3$	*Assessment*
J	
Up to and including 40	Requirement not fulfilled
Including and over 47	Requirement fulfilled

If the value of $\overline{x}_3$ lies between 40 J and 47 J, three additional specimens shall be prepared and tested, and the results added to those previously obtained to form a new average $\overline{x}_6$. If the value of $\overline{x}_6$ is 47 J or above, the wire-flux combination shall be deemed to have fulfilled the requirements.

If the value of $\overline{x}_6$ is less than 47 J, further six specimens shall be prepared using the same batch of wire and fluxes, if possible and tested, and the results added to the previous value of $\overline{x}_6$ to form a new average $\overline{x}_{12}$ the value of which shall not be less than 47 J.

23.3 Chemical Composition

The percentage contents of carbon, manganese, silicon, sulphur and phosphorus in the deposited weld metal from the all-weld test piece may be reported. The sulphur and phosphorus content shall not exceed 0.05 percent each.

23.4 Transverse Tensile Tests

Two transverse tensile specimens shall be prepared in accordance with the method specified in **20.9.6**.

23.5 Transverse Bend Test

Four transverse bend specimens shall be prepared and tested in accordance with the method specified in **20.9.7**.

Each test specimen satisfies, if bent through an angle of 120° over a former having a diameter equal to three times the thickness of the specimens, no crack or defect at the outer surface of the specimen is greater than 3 mm measured across the specimen or 1.5 mm along the length of the specimen. Premature failure at the corners of the specimens shall not be considered cause of failure.

24 TWO-RUN WELDING: LONGITUDINAL WELD TENSILE STRENGTH 400-600 N/mm^2 (41-61 kgf/mm^2), YIELD STRESS NOT LESS THAN 300 N/mm^2 (31 kgf/mm^2), NOT COVERED BY 25 OR 26

24.1 Longitudinal Weld Tensile Test

One longitudinal weld tensile test specimen shall be prepared and tested in accordance with the method specified in **20.9.12**.

The tensile strength of specimen shall be within the range 400 - 600 N/mm^2 (41-61 kgf/mm^2) and the yield stress not less than 300 N/mm^2 (31 kgf/mm^2). The elongation shall be not less than 22 percent.

24.2 Butt-Weld Impact Tests

Three impact test specimens shall be prepared in accordance with **20.9.14**. The average of the three impact values shall not be less than the following:

Grade	*Average Impact Values, Min*		*Testing Temperature* °C
	J	kgf/m	
T11	35	3.5	(Room Temp) 20 Approx
T12	35	3.5	0 ± 1
T13	35	3.5	– 20 ± 1
T14	35	3.5	– 40 ± 1

The results of the impact shall be assessed as specified in **24.2.1**.

24.2.1 The average $\overline{x}_3$ of the results of the three tests shall be assessed as follows:

$\overline{x}_3$	*Assessment*
J	
Up to and including 30	Requirement not fulfilled
Including and over 35	Requirement fulfilled

If the value of $\overline{x}_3$ lies between 30 J and 35 J, three additional specimens shall be prepared and tested, and the results added to those previously obtained to form a new average $\overline{x}_6$. If the value of $\overline{x}_6$ is 35 J or above, the wire-flux combination shall be deemed to have fulfilled the requirements. If the value of $\overline{x}_6$ is less than 35 J, further six specimens shall be prepared using the same batch of wire and fluxes, if possible and tested, and the results added to the previous value of $\overline{x}_6$ to form a new average $\overline{x}_{12}$ the value of which shall not be less than 35 J.

24.3 Chemical Composition

The percentage contents of carbon, manganese, silicon, sulphur and phosphorus in the deposited weld metal from the all-weld test piece may be reported. The sulphur and phosphorus content shall not exceed 0.05 percent each.

24.4 Transverse Tensile Tests

Two transverse tensile specimens shall be prepared in accordance with the method specified in **20.9.6**.

The tensile strength of each specimen shall not be less than 400 N/mm^2.

24.5 Transverse Bend Test

Four transverse bend specimens shall be prepared and tested in accordance with the method specified in **20.9.7**.

Each test specimen satisfies if bent through an angle of 120^{o} over a former having a diameter equal to three times the thickness of the specimens no crack or defect at the outer surface of the specimen is greater than 3 mm measured across the specimen or 1.5 mm along the length of the specimen. Premature failure at the corners of the specimens shall not be considered cause of failure.

25 TWO-RUN WELDING: LONGITUDINAL WELD TENSILE STRENGTH 500-650 N/mm^2 (51-66 kgf/mm^2), YIELD STRESS NOT LESS THAN 350 N/mm^2 (36 kgf/mm^2), NOT COVERED BY 24 OR 26

25.1 Longitudinal Weld Tensile Test

One longitudinal weld tensile test specimen shall be prepared and tested in accordance with the method specified in **20.9.12**.

The tensile strength of specimen shall be within the range 500-650 N/mm^2 (51-66 kgf/mm^2) and the yield stress not less than 350 N/mm^2 (36 kgf/mm^2). The elongation shall be not less than 22 percent.

25.2 Butt-Weld Impact Tests

Three impact test specimens shall be prepared in accordance with **20.9.14**. The average of the three impact values shall not be less than the values given as follows.

Grade	*Average Impact Values, Min*		*Testing Temperature* °C
	J	kgf/m	
T 21	40	4.0	(Room Temp) 20 Approx
T 22	40	4.0	0 ± 1
T 23	40	4.0	– 20 ± 1
T 24	40	4.0	– 40 ± 1

The results of the impact shall be assessed as specified in **25.2.1**.

25.2.1 The average $\overline{x}_3$ of the results of the three tests shall be assessed as follows:

$\overline{x}_3$ J	*Assessment*
Up to and including 34	Requirement not fulfilled
Including and over 40	Requirement fulfilled

If the value of $\overline{x}_3$ lies between 34 J and 40 J, three additional specimens shall be prepared and tested, and the results added to those previously obtained to form a new average $\overline{x}_{6.}$ If the value of $\overline{x}_6$ is 40 J or above, the wire-flux combination shall be deemed to have fulfilled the requirements.

If the value of $\overline{x}_6$ is less than 40 J, further six specimens shall be prepared using the same batch of wire and fluxes, if possible and tested, and the results added to the previous value of $\overline{x}_6$ to form a new average $\overline{x}_{12}$ the value of which shall not be less than 40 J.

25.3 Chemical Composition

The percentage contents of carbon, manganese, silicon, sulphur and phosphorus in the deposited weld metal from the all-weld test piece may be reported. The sulphur and phosphorus content shall not exceed 0.05 percent each.

25.4 Transverse Tensile Tests

Two transverse tensile specimens shall be prepared in accordance with the method specified in **20.9.11**.

The tensile strength of each specimen shall not be less than 350 N/mm^2 (36 kgf/mm^2).

25.5 Transverse Bend Test

Four transverse bend specimens shall be prepared and tested in accordance with the method specified in **20.9.13**.

Each test specimen satisfies, if bent through an angle of 120° over a former having a diameter equal to three times the thickness of the specimens no crack or defect at the outer surface of the specimen is greater than 3 mm measured across the specimen or 1.5 mm along the length of the specimen. Premature failure at the corners of the specimens shall not be considered cause of failure.

26 TWO-RUN WELDING: LONGITUDINAL WELD TENSILE STRENGTH 550-700 N/mm^2 (56-71 kgf/mm^2), YIELD STRESS NOT LESS THAN 450 N/mm^2 (46 kgf/mm^2)

26.1 Longitudinal Weld Tensile Test

One longitudinal weld tensile test specimen shall be prepared and tested in accordance with the method specified in **20.9.11**.

The tensile strength of specimen shall be within the range 550-700 N/mm^2 (56-71 kgf/mm^2) and the yield stress not less than 450 N/mm^2 (46 kgf/mm^2). The elongation shall be not less than 22 percent.

26.2 Butt-Weld Impact Tests

Three impact test specimens shall be prepared in accordance with **20.9.14**. The average of the three impact values shall not be less than the following:

Grade	*Average Impact Values, Min*		*Testing Temperature* °C
	J	kgf/m	
T 31	47	4.7	(Room Temp) 20 Approx
T 32	47	4.7	0 ± 1
T 33	47	4.7	– 20 ± 1
T 34	47	4.7	– 40 ± 1

The results of the impact shall be assessed as specified in **26.2.1**.

26.2.1 The average $\overline{x}_3$ of the results of the three tests shall be assessed as follows:

$\overline{x}_3$ J	*Assessment*
Up to and including 40	Requirement not fulfilled
Including and over 47	Requirement fulfilled

If the value of $\overline{x}_3$ lies between 40 J and 47 J, three additional specimens shall be prepared and tested, and the results added to those previously obtained to form a new average $\overline{x}_6$. If the value of $\overline{x}_6$ is 47 J or above, the wire-flux combination shall be deemed to have fulfilled the requirements.

If the value of $\overline{x}_6$ is less than 47 J, further six specimens shall be prepared using the same batch of wire and fluxes if possible and tested, and the results added to the previous value of $\overline{x}_6$ to form a new average $\overline{x}_{12}$ the value of which shall not be less than 47 J.

26.3 Chemical Composition

The percentage contents of carbon, manganese, silicon, sulphur and phosphorus in the deposited weld metal from the all-weld test piece may be reported. The sulphur and phosphorus content shall not exceed 0.05 percent each.

26.4 Transverse Tensile Tests

Two transverse tensile specimens shall be prepared in accordance with the method specified in **20.9.11**.

The tensile strength of each specimen shall not be less than 450 N/mm^2 (46 kgf/mm^2).

26.5 Transverse Bend Test

Four transverse bend specimens shall be prepared and tested in accordance with the method specified in **20.9.13**.

Each test specimen satisfies, if bent through an angle of 120° over a former having a diameter equal to three times the thickness of the specimens no crack or defect at the outer surface of the specimen is greater than 3 mm measured across the specimen or 1.5 mm along the length of the specimen. Premature failure at the corners of the specimens shall not be considered cause of failure.

27 PACKING

27.1 Reels of wire shall be suitably packed to guard against atmospheric influence, damage, or deterioration during storage, transit and inspection.

27.2 If the condition of the wire is such that special protection during storage or special treatment before use is desirable, the manufacturer shall give details of such special protection or treatment on the package.

28 MARKING

28.1 *Filler Wire*

Each reel or coil of wire shall be clearly marked with the following information:

a) Classification coding,
b) Name of manufacturer,
c) Trade designation of wire,
d) Wire size,
e) Cast number,
f) Net weight of the reel/coil, and
g) Batch No.and date of manufacture.

28.2 Flux

The packaging shall be clearly marked with the following details:

a) Trade designation;
b) Classification as per this specification (wire flux combination);
c) Batch No. and date of manufacture;
d) Net weight;
e) Manufacturer’s name;
f) Particle size range;
g) Range of Welding parameters, such as, current, polarity, voltage speed, etc, for which the flux is suitable; and
h) Redrying temperature and time.

28.3 BIS Certification Marking

The material may also be marked with the Standard Mark.

28.3.1 The use of the Standard Mark is governed by the provisions of the *Bureau of Indian Standards Act*, 1986 and the Rules and Regulations made thereunder. The details of conditions under which the license for the use of the Standard Mark may be granted to manufacturers or producers may be obtained from the Bureau of Indian Standards.

ANNEX A

(*Clause* 13.2.2)

METHOD OF MANUFACTURE, PARTICLE SIZE AND CURRENT CARRYING CAPACITY OF FLUX

A-1 METHOD OF MANUFACTURE OF FLUX

Submerged arc welding fluxes are granular, fusible mineral components in various proportions and quantity manufactured by different methods. The general types are named by their method of manufacture and known as fused, agglomerated and mechanically mixed fluxes. Each type have certain unique characteristics which affect mechanical and chemical property of weld metal, operating performance and handling of environmental variables.

A-1.1 Fused Flux

The fused fluxes are mixture of silica metal oxides with a small amount of halide salts which are completely fused to form a metallic silicate glass. This cooled product of the furnace is then ground to the required particle sizes for adequate performance.

A-1.2 Agglomerated Flux

Agglomerated fluxes are intimate mixture of finely divided oxides of alkaline earth metals manganese, aluminium, silicon, titanium or zirconium, etc. These mixtures also contain de-oxidizers, such as, silico manganese, ferro manganese, ferro silicon or similar alloys and small amount of halogen salts. They may also contain alloying elements either as elemental metal or as ferro alloys. These are bonded together with a suitable binder and treated so that hard granules are formed in which individual ingredients are uniformly distributed.

A-1.3 Mechanically Mixed Flux

Mechanically mixed fluxes are mechanical mixture of several fused or bonded fluxes in varying proportions. Mechanical mixtures may also be of finely divided minerals and metallic de-oxidizers in proportions necessary for a desired performance.

A-2 PARTICLE SIZE RANGE

The particle category is not a part of the flux designation but shall be used for information in the marking of packaging units. The particle category shall be indicated by the symbol for the smallest and largest particle sizes according to Table 7 or expressed in millimetre.

Table 7 Particle Size and Range

Sl No. (1)	Particle Sizes mm (2)	Symbols (3)
i)	2.5	25
ii)	2.0	20
iii)	1.6	16
iv)	1.25	12
v)	0.8	8
vi)	0.5	5
vii)	0.315	3
viii)	0.2	2
ix)	0.1	1
x)	<0.1	D

NOTE — Example of a typical symbol for particle size range is 2-16 (0.2 mm-1.6 mm).

A-3 CURRENT CARRYING CAPACITY

The current carrying capacity of a flux depends on various welding conditions and is not indicated in the flux designation.

NOTE — For purposes of comparison the manufacturer shall indicate in his literature or data sheets, the current carrying capacity of the flux. This is assessed as being the maximum current carried by a 4.0 mm diameter wire under standard conditions such that a regular and uniform weld bead is obtained. The standard conditions for such a test are defined as follows:

Travel speed : 550 mm/min
Electrode extension : 35 mm
Type of current : Direct current
Electrode polarity : Electrode positive
Arc voltage : 35 ± 1 V
Plate thickness : 25 mm

Whilst the maximum current value may be defined in this manner it should be recognized that in actual use this value may be increased in certain instances, for example, high travel speeds, multi-wire system, etc.

ANNEX B

(*Clause* 13.2.3)

SYMBOLS AND TYPE OF FLUX AND CHARACTERISTIC CHEMICAL CONSTITUENTS

B-1 The type of flux and characteristics chemical constituents shall be as given in Table 8.

Table 8 Symbol and Type of Flux and Characteristic Chemical Constituents

Sl No. (1)	Symbol and Type (2)	Characteristic Chemical Constituents (3)	Limit of Constituent (4)
i)	MS Manganese-Silicate	$MnO + SiO_2$ CaO	50 *Min* 15 *Max*
ii)	CS Calcium-Silicate	$CaO + MgO + SiO_2$ $CaO + MgO_2 + MnO$	55 *Min* 15 *Min*
iii)	ZS Zirconium-Silicate	$ZrO_2 + SiO_2 + MnO$ ZrO_2	45 *Min* 15 *Min*
iv)	RS Rutile-Silicate	$TiO_2 + SiO_2$ TiO_2	50 *Min* 20 *Min*
v)	AR Aluminium-Rutile	$Al_2O_3 + TiO_2$	40 *Min*
vi)	AB Aluminium-Basic	$Al_2O_3 + CaO + MgO$ Al_2O_3 CaF_2	40 *Min* 20 *Min* 22 *Max*
vii)	AS Aluminium-Silicate	$Al_2O_3 + SiO_2 + ZrO_2$ $CaF_2 + MgO$ ZrO_2	40 *Min* 30 *Min* 5 *Min*
viii)	AF Aluminium-Fluoride-Basic	$Al_2O_3 + CaF_2$	70 *Min*
ix)	FB Fluoride-Basic	$CaO + MgO + CaF_2 + MnO$ SiO_2 CaF_2	50 *Min* 20 *Max* 15 *Min*
x)	Z	Any other composition	

NOTE — Description of the characteristics of each type of flux is given in Annex C.

ANNEX C

(*Clause*13.2.3 and *Table* 8)

DESCRIPTION OF FLUX TYPES

C-1 MANGANESE - SILICATE TYPE, MS

Welding fluxes of this type contain essentially MnO and SiO_2. Generally, they are characterized by a high manganese transfer to the weld metal, so that they are preferably used in combination with low-manganese wire electrodes. Silicon pick-up the weld metal is also high. Many fluxes of this type give weld metals of limited toughness which is partly attributable to a high weld oxygen content.

Manganese-silicate fluxes have a relatively high current carrying capacity and are suitable for high welding speeds. The weld metal shows good resistance to porosity, even on rusty plate. The weld contour is regular and the weld interface free from undercut.

Toughness limitations usually preclude the use of these fluxes in multi-pass welding of thick sections, but they are well suited to fast welding of thinner materials and to fillet welding.

C-2 CALCIUM - SILICATE TYPE, CS

Welding fluxes of this type are composed essentially of CaO, MgO and SiO_2. The group comprises a range of types, the more acid ones having the highest current carrying capacity of all fluxes and contributing high amounts of silicon to the weld metal. These fluxes are suitable for two-pass welding of thick sections where mechanical property requirements are not too stringent.

More basic fluxes within the group give less silicon pick-up and may be used for multi-pass welding where strength and toughness requirements are more stringent. The current carrying capacity of the fluxes tends to decrease with increasing flux basicity but the weld profile would be smooth and free from undercut.

C-3 ZIRCONIUM - SILICATE TYPE, ZS

Welding fluxes of this type are composed of ZrO_2 and SiO_2 as their main constituents. These fluxes are recommended for making .high speed, single-pass welds on clean plate and sheet steel. The good wetting action of the slag provides the characteristics needed to make uniform welds at high speed without undercut.

C-4 RUTILE - SILICATE TYPE, RS

Welding fluxes of this type are composed to TiO_2 and SiO_2 as their main constituents. Beside a high manganese burn out, these fluxes produce a high silicon pick-up in the weld deposit. Thus, they can be used in conjunction with wire electrodes having a medium or high manganese content. The toughness of the weld remains limited due to a relative high oxygen content.

Their current carrying capacity is reasonably high, which permits single and multi-wire welding at high travel speeds. A typical field of application is two-run welds (one-run from each side of the joint) in fabrication of large diameter pipes.

C-5 ALUMINIUM - RUTILE TYPE, AR

These fluxes contain essentially Al_2O_3 and TiO_2. There is an average manganese and silicon transfer to the weld metal. Due to their high slag viscosity, this type features a large number of advantageous operating characteristics, such as, good weld appearance, high welding speed and very good slag detachability, especially in fillet welds. The fluxes are suitable for operation on dc and ac thus are suitable for operation on welding. Due to their relatively high oxygen content they produce medium mechanical properties.

The main fields of application include the welding of thin walled containers and pipes, tube-web-tube joints of finned tubes, fillet welds in steel constructions and ship-building.

C-6 ALUMINIUM - BASIC TYPE, AB

The ratio of basic to acid compounds in a flux is known as the basicity value. Besides Al_2O_3, as their main constituent, these fluxes contain essentially MgO and CaO. They produce a medium manganese transfer to the weld deposit. Due to the high Al_2O_3 content the liquid slag is ‘short’ and there is an optimum balance of weld metal performance and operability characteristics. Operating properties of these fluxes are good on account of their basic slag characteristics (medium oxygen content) good toughness of the weld metal is achieved especially in two-run welding.

They are used extensively for the welding of unalloyed and low alloyed structural steels in various field of application.

They can be used on dc and ac employing the multi-pass or two-run technique.

C-7 ALUMINIUM - SILICATE TYPE, AS

Fluxes of this type are characterized by a moderate high level of basic compounds, such as, MgO and CaF_2, balanced with substantial amounts of silicates, Al_2O_3 and ZrO_2. The metallurgical behaviour of these fluxes is mostly neutral but manganese burn out is also possible. Thus, wire electrodes with higher manganese level are preferably used.

As a result of their high slag basicity, a low oxygen high-purity weld is obtained. On account of the basic flux characteristics, together with a low slag viscosity, these fluxes feature corresponding operating characteristics, such as, limited current carrying capacity and welding speed. Slag release and weld bead profile are good also, if narrow-gap process is applied. Although welding on dc is preferred (low weld hydrogen content) some of these fluxes can also be used on ac and thus on multiwire systems. This type of fluxes, as the fluoride-basic fluxes, are recommended for multi-pass welding, in particular when high toughness requirements must be met. Therefore, the preferred application is the welding of high-tensile fine grain steels, such as, in the field of pressure vessels, nuclear components or offshore constructions.

C-8 ALUMINIUM - FLUORIDE - BASIC TYPE, AF

Fluxes of this type are composed of Al_2O_3 and CaF_2 as main constituents. These fluxes are primarily applied in combination with alloyed wires as stainless steel and Ni-base alloys. The weld deposit is neutral with respect to Mn, Si and other alloying elements. Due to the high fluoride content these fluxes provide a good wetting action and weld surface appearance. The arc voltage is to be set at a higher level, compared to an aluminate-basic type.

C-9 FLUORIDE - BASIC, FB

Fluxes of this type are characterized by a high level of basic compounds, such as, CaO, MgO, MnO and of CaF_2 but the level of SiO_2 is low. The metallurgical behaviour is mainly neutral but manganese burn-off is also possible. Thus, it is preferable to use wire electrodes with higher manganese level.

As a result of high slag basicity, a low oxygen high purity weld is obtained. A maximum weld metal toughness down to very low temperatures can be achieved. On account of the basic flux characteristics, together with a low slag viscosity, they have limited current carrying capacity and welding speed. Slag release and weld bead performance are good even, if the narrow-gap process is applied. Although welding on dc is preferred to produce a low weld hydrogen content, some of these fluxes can also be used on ac and thus on multi-wire systems.

They are recommended for multi-pass welding, in particular when there are high toughness requirements. The preferred application is the welding of high tensile fine grain steels, for example, pressure vessels, nuclear components or offshore constructions.

Fluxes of this type may also be applicable for welding stainless steel and nickel base alloys.

C-10 TYPES WITH OTHER COMPOSITION, Z

Other types are not covered by this description.

ANNEX D

(*Clauses* 20.1 *and* 20.9.9.2)

PARENT METAL FOR TEST PLATES

D-1 PARENT METAL

D-1.1 The parent metal used in preparing test piece and test specimen shall be as given in Table 9.

D-1.2 The plates may be in the as-rolled or normalized condition and the chemical composition and tensile strength shall be verified from the test on the plate before the test pieces are prepared. These results should be made available on request. Although steel complying with the requirements of Table 9 is used for approval purpose, there can be variations in composition within any particular grade. When other steels are used in practice, different properties may be obtained and if the consistency of the properties is important, the user should consult the consumables supplier and should make his own tests to check the suitability of a particular wire-flux combination.

Table 9 Parent Metal For Test Plates

Sl No.	Clause No.	Parent Metal Specification	Range of Tensile Strength	
			N/mm ^{2}	Kgf/mm^2
(1)	(2)	(3)	(4)	(5)
i)	21 and 22, 23 and 24	IS 2062	410 - 510 410 - 510	42 - 52 42 - 52
ii)	25	IS 2041	510 - 610	52 - 62
iii)	26	IS 2062	540 - 710	55 - 70

(*Continued from second cover*)

Manufacturers usually produce a range of fluxes based on various combinations of compounds. The ratio of basic to acid compounds in a flux is known as the basicity value and the recent work indicates that the higher the basicity value, the higher will be the impact properties of the weld metal. This is a complex subject, and in case when weld metal ductility is important, the user is advised to consult the manufacturer of consumables, since the notch toughness of weld metal is a function not only of the flux chemistry but also of the weld metal chemistry and the weld micro-structure.

The suitability of a combination of wire and flux cannot be based solely on the numerical results obtained from the tests specified in this standard and other factors relative to the particular fabrication have to be taken into account. Amongst these are the minimum temperature that the fabrication will experience in service and the maximum stress to which the weld metal will be subjected. Also, the weld contour appearance and the penetration may be important considerations. The user is, therefore, advised to carry out procedure tests to simulate his production application.

Although combinations of wires and fluxes supplied by different companies may be approved for the same grade, individual wires and fluxes are not necessarily interchangeable.

In the formulation of this standard, due consideration has been given to the manufacturing and trade practices followed in this field in this country. Assistance has been derived from the following International Standards:

International Standard	*Title*
ANSI/AWS-A 5.17/ 5.17M : 2007	Specification for 'Carbon steel electrodes and fluxes for submerged arc welding'
Pr EN-760: 2004	Welding consumables — Fluxes for submerged arc welding — Classification
Pr EN 756: 2004	Welding consumables — Solid wires, solid wire-flux and tubular cored electrodes — Flux combinations for submerged arc welding of non alloy and fine grain steels — Classification
BS 4165:1971	Specification for electrode wires and fluxes for the submerged-arc welding of carbon steel and medium tensile steel
IIS/IIW-385-72	Classification and symbolization of bare steel wire electrodes and fluxes for submerged-arc welding of structural steel
IIS/IIW-XII-1374-94	Specification for classification of fluxes for submerged arc welding of unalloyed, low alloy and high alloy steels

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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